The Theater Missile Defense System Exerciser

TMDSE — Build a Little, Test a Little

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Theater ballistic missiles and cruise missiles are a major threat to U.S. forces deployed almost anywhere in the world. To counter this threat, an extremely sophisticated family of theater missile defense (TMD) weapon systems has been developed. To achieve the maximum firepower effectiveness, however, today's TMD Family of Systems (FoS) must be highly interoperable to counter a broad spectrum of threats, environments, and deployment scenarios.

The Theater Missile Defense System Exerciser, or TMDSE, offers the only hardware-in-the-loop (HWIL) test capability available to integrate the entire TMD FoS and test interoperability issues that exist between the separately developed TMD systems.

The TMDSE is a computer-based test tool used to verify interoperability between geographically distributed TMD systems and sensors. This tool "drives" tactical TMD weapon systems with a time-synchronized simulated environment, including threats (theater ballistic missiles, cruise missiles, and aircraft), weather, and terrain.

In June of 1994, the U.S. Army Program Executive Office for Air and Missile Defense (PEO AMD) located in Huntsville, Ala., successfully conducted a Proof-of-Principle (POP) demonstration of a test tool concept that would later become the TMDSE. This POP demonstration, that validated the concept, illustrated the interconnection of two remote TMD tactical hardware sites (the U.S. Army PATRIOT Flight Mission Simulator [FMS] in Bedford, Mass.; and the U.S. Army Joint Tactical Ground Station [JTAGS] located in Azusa, Calif.), simultaneously driven in real time with a common theater test environment.

Following the TMDSE POP, the Ballistic Missile Defense Organization (BMDO) then directed that PEO AMD in Huntsville, Ala., develop the TMDSE, thereby providing the capability to verify that the TMD FoS are integrated and can effectively interoperate across the spectrum of threats, environments, deployments, and contingencies that are delineated in their respective operational requirements documents.

Under the direction of the Deputy for Acquisition/Theater Missile Defense, BMDO, TMDSE development is in its third year and proceeding to an enhanced Build 2 capability. Air Force Lt. Col. Steve McQueen, BMDO/AQI, Systems Integration/BMC3, is the Program Integrator. As executing agent for BMDO, PEO AMD is responsible for the development of the TMDSE Control Segment, development of the Army "drivers," and integration of all Joint elements.

The TMD systems that are integrated into TMDSE will be combinations of existing inventory, product upgrades, and new systems that evolve to enhance mission effectiveness. Its phased, incremental development approach also allows TMDSE to be systematically upgraded to higher levels of fidelity and complexity to support the evolving TMD architecture and its resulting test needs.

As the complexity of the deployable TMD Systems and their operating environments increases, so must the capability of the TMDSE. The implementation of BMDO's direction will be accomplished through the phased development of the TMDSE. Each phase during this development progression is referred to as a Build.

TMDSE Build 1 Configuration

TMDSE's developers, Nichols Research Corporation and Teledyne Brown Engineering, of Huntsville, Ala., completed the TMDSE Build 1 config-

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Washburn is a professional engineer with the Program Executive Office for Air and Missile Defense in Huntsville, Ala., and a member of the Army Acquisition Corps (AAC). He is also the executing agent and program manager for the Army portion of the TMDSE Program. Washburn has almost 10 years of prior simulation experience, including work as program manager on the following simulations: Extended Air Defense Simulation, Israeli Testbed, and the United Kingdom Testbed.
Morash is a software engineer with the Program Executive Office for Air and Missile Defense in Huntsville, Ala., and a member of the Corps Eligible program of the AAC. He is also the Assistant Program Manager of the Army portion of the TMDSE Program. Morash has six years of prior simulation experience, including three years on the Extended Air Defense Testbed.

U.S. Army digitized photos/illustrations

uration in April 1996. Upon completion, the TMDSE Build 1 had 200,000 lines of Ada code. The TMDSE Builds, leveraging heavily from the various Major Defense Acquisition Programs and other defense systems that make up the TMD FoS, make TMDSE a very cost-effective HWIL test capability. As configured, TMDSE interfaces directly with each weapon system via its existing tactical driver, and does not require co-location of test articles. Five sites jointly participated in the TMDSE Build 1 configuration:

- U.S. Army PATRIOT Engagement Control Station (ECS) and Information Control Center (ICC) at the U.S. Army's Missile Command (MICOM) Software Engineering Directorate, Huntsville, Ala.
- U.S. Navy AEGIS Weapon System at the Naval Surface Warfare Center (NSWC) AEGIS Computer Center (ACC) at Dahlgren, Va.
- U.S. Army Joint Tactical Ground Station (JTAGS),PEO AMD, Huntsville, Ala. (The actual JTAGS shelter driver was and is housed at Aerojet Corporation in Azusa, Calif.)

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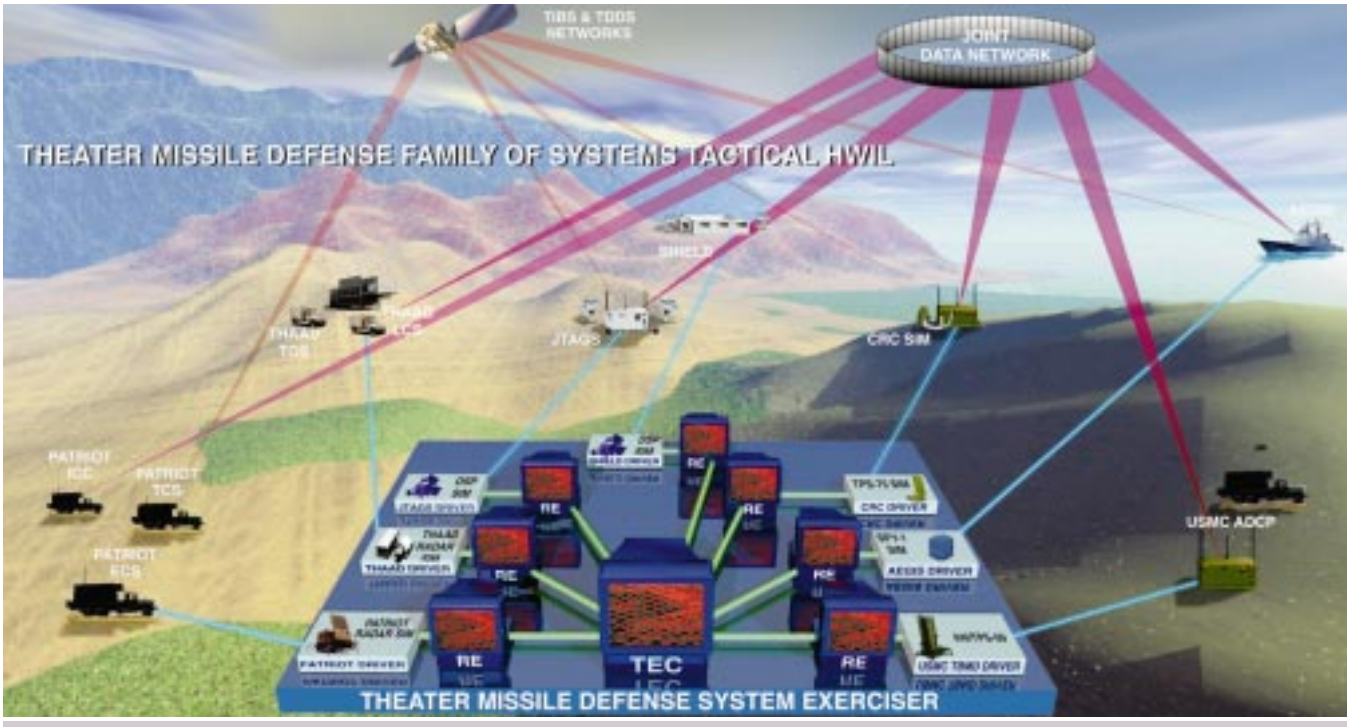
- U.S. Air Force SHIELD at the Joint National Test Facility (JNTF), Falcon Air Force Base, Colorado Springs, Colo.
- U.S. Air Force Control and Reporting Center (CRC) at the Theater Air Command and Control Simulation Facility (TACCSF), Kirtland Air Force Base, Albuquerque, N.M.

One of the things that separates the TMDSE from other simulations and contributes to its uniqueness is its use of real tactical hardware and real tactical communications. During actual TMDSE execution, the TMDSE makes use of a real PATRIOT ICC and real PATRIOT TMDSE Control Segment shelters, real AEGIS weapon system computers and software, real JTAGS computers and software, and real satellite broadcasts. (The simulated threat "injected" into the JTAGS and SHIELD systems will generate real Tactical Information Broadcast Service [TIBS] and TRAP Data Distribution System [TDDS] cueing messages that will be received by the PATRIOT, AEGIS Weapon System, and CRC elements.)



THE THEATER MISSILE DEFENSE SYSTEM EXERCISER OR TMDSE OFFERS THE ONLY TACTICAL HARDWARE-IN-THE-LOOP (HWIL) TEST CAPABILITY AVAILABLE TO INTEGRATE THE ENTIRE THEATER MISSILE DEFENSE FAMILY OF SYSTEMS (TMD FOS) AND TEST INTEROPERABILITY ISSUES THAT EXIST BETWEEN THE SEPARATELY DEVELOPED TMD SYSTEMS.

The TMDSE system is connected to its remote sites using two separate networks: one that addresses the test control functionality of the system, and the other that provides the tactical communications network for the systems under test. These communication networks consist of a combination of local and wide area networks, high bandwidth (i.e., T1 1.544 megabit per second) telephone lines, KG-194 encryption devices, and secure telephones (STU-IIIs), which connect the TBE Test Exercise Controller (TEC) hub to the geographically distributed TMD Tactical Drivers.

The first of these is the TMDSE test control network, which is comprised of high band width (T1) encrypted telephone lines that join the TEC with all Remote Environments at each Tactical Driver site. This network provides a common, synchronized environment to the various tactical systems via a common standardized set of Distributed Interactive Simulation (DIS) protocol data units (PDU). Using DIS PDUs, TMDSE injects a real-time, common threat scenario into real, geographically distributed tactical sensors and weapon systems. The tactical systems respond in real time via their respective tactical communication data nets, including TIBS/TDDS and the Joint Data Net, allowing each individual TMD system to operate synergistically in a tactically realistic battlefield.

This test control network allows the TMDSE to —

- generate realistic scenarios, including natural (weather and terrain) and artificial environments, including tactical missiles and air-breathing threats;
- generate realistic missile interceptor flyouts;
- generate realistic interceptor and threat debris in real time;
- coordinate and synchronize the stimulation of the track processing systems; and
- coordinate and synchronize dynamic events that are a result of offensive/defensive actions. ("Dynamic" events, as opposed to "scripted" events such as tactical missile flyouts, are the defensive actions taken by the tested weapon systems in response to the scripted threats. For example, the reaction(s) of a PATRIOT fire unit to approaching tactical missiles or aircraft must be represented dynamically in real time.)

The second network used, the tactical communications network, connects the tactical systems to each other. These interfaces must appear to be the natural communications expected of the TMD components with regard to protocol, message formatting, and routing selection. Actual Joint Tactical Information Distribution System (JTIDS) radio terminals cost approximately $1 million each and operate via line-of-sight, which means that they are restricted to distances of 30-50 kilometers. Due to the high cost of these radios and the fact that geographically distributed TMDSE systems are sometimes separated by distances of hundreds or thousands of miles, another means had to be found to emulate tactical communications.

For TMDSE, the U.S. Naval Command, Control, and Ocean Surveillance Center's Link 16 Emulator and Communications Monitor (the "NRaD Gateway") provided the tactical communication link connectivity between the individual weapon system platforms using the Tactical Digital Information Link (TADIL) J protocols and message formats emulating a JTIDS. Future planned enhancements to the NRaD Gateway will increase the fidelity of the TMDSE and allow land-line emulation of satellite transmissions.

In the first quarter of fiscal year 1997, the TMDSE Build 1 configuration was installed at the Joint National Test Facility (JNTF) located at Falcon Air Force Base in Colorado Springs, Colo. BMDO designated the JNTF to be the operational facility where FoS tests will be run. PEO AMD, however, will continue as the developer for the follow-on configurations.

TMDSE Build 2 Configuration

The TMDSE Build 2 is scheduled to be completed by July 1997. By the end of third quarter, fiscal year 1997, the TMDSE Build 2 requirements and functional capabilities will demonstrate an evolving capability for TMD system integration and interoperability testing. In addition to the original five TMDSE Build 1 systems (PATRIOT, AEGIS, CRC, JTAGS, and SHIELD), the following two additional TMD Tactical Systems will participate in the Build 2 configuration:

- U.S. Army Theater High Altitude Area Defense (THAAD) weapon system, PEO AMD, Huntsville, Ala.
- U.S. Marine Corps HAWK TPS-59 radar system, USMC Systems Command, Syracuse, N.Y.

TMDSE Verification, Validation, and Accreditation (VV&A)

The technical difficulties and costs associated with ensuring adequate verification and validation (V&V) of modeling and simulation (M&S) are major challenges in successfully executing a simulation development enterprise within the DoD. In today's current regulatory environment, DoD and Service policies and directives generally mandate that M&S be subjected to a formal, structured verification, validation, and accreditation (VV&A) program. Within the Services, and BMDO in particular, guidance and oversight for M&S VV&A is becoming quite explicit. Timely and successful accreditation of simulations with embedded legacy models and codes, such as TMDSE, require explicit, focused V&V evaluations that are tied to the simulations' intended use.

The best means for accomplishment of this complex task is a rigorous, focused V&V and evaluation effort, which is adaptable to the particular unit-under-test. Currently, for TMDSE a tailored V&V program is being pursued that is based on —

- leveraging ongoing, system-level simulation development, test, and V&V activities;

THE TMDSE BUILD 1 CONFIGURATION CONSISTED OF JOINT PARTICIPATION BY THE FOLLOWING FIVE SITES: (A) U.S. ARMY PATRIOT ENGAGEMENT CONTROL STATION (ECS) AND INFORMATION CONTROL CENTER (ICC) AT THE U.S. ARMY'S MISSILE COMMAND (MICOM) SOFTWARE ENGINEERING DIRECTORATE (SED), HUNTSVILLE, ALA.; (B) U.S. NAVY AEGIS WEAPON SYSTEM AT THE NAVAL SURFACE WARFARE CENTER (NSWC) AEGIS COMPUTER CENTER (ACC) AT DAHLGREN, VA.; (C) U.S. ARMY JOINT TACTICAL GROUND STATION (JTAGS), PEO AMD, HUNTSVILLE, ALA. [(F) THE ACTUAL JTAGS SHELTER DRIVER WAS AND IS HOUSED AT AEROJET CORPORATION IN AZUSA, CALIFORNIA]; (D) U.S. AIR FORCE SHIELD AT THE JOINT NATIONAL TEST FACILITY (JNTF), FALCON AIR FORCE BASE, COLORADO SPRINGS, COLO.; AND (E) U.S. AIR FORCE CONTROL AND REPORTING CENTER (CRC) AT THE THEATER AIR COMMAND AND CONTROL SIMULATION FACILITY (TACCSF), KIRTLAND AIR FORCE BASE, ALBUQUERQUE, N.M. IN ADDITION TO THE ORIGINAL FIVE, TMDSE BUILD 1 SYSTEMS (PATRIOT, AEGIS, CRC, JTAGS, AND SHIELD), TWO ADDITIONAL TMD TACTICAL SYSTEMS WILL PARTICIPATE IN THE BUILD 2 CONFIGURATION: (G) U.S. ARMY THEATER HIGH ALTITUDE AREA DEFENSE (THAAD) WEAPON SYSTEM, PEO AMD, HUNTSVILLE, ALA.; AND (H) U.S. MARINE CORPS HAWK TPS-59 RADAR SYSTEM, USMC SYSTEMS COMMAND, SYRACUSE, N.Y.

- verifying TMDSE through a series of well-defined and coordinated functional configuration audit activities;
- validating TMDSE at the system level by explicitly linking TMDSE validation activities to existing, ongoing, or planned system test activities as the principal source of "real world" data; and
- generating the essential information necessary for V&V reports and findings, which provide the evidence required to support the accreditation decision by potential TMDSE users and operational testers.

The set of specific validation activities selected for execution are being closely coordinated with the individual system developers and will be based upon TMDSE accreditation data needs, the realities of the system programs, and the fixed resources available for TMDSE V&V within the respective Services and BMDO. The validation activities for TMDSE are being defined by the sponsor for execution by the respective system simulation activity.

Hardware-in-the-Loop Test (HWILT)

The fiscal year 1996 BMDO Hardware-in-the-Loop Test (HWILT-96) was conducted in September 1996 using the TMDSE Build 1 software. Navy Cmdr. Don Gold of BMDO was the program integrator for the HWILT-96. The test was executed and controlled under the direction of Army Lt. Col. Chuck Treece of PEO AMD, from the develop-

mental TMDSE Test Exercise Controller located at Teledyne Brown Engineering in Huntsville, Ala.

The HWILT-96 tactical weapon system participants generated and distributed tactical communication messages, including Joint Data Network, TADIL-J, and live TIBS and TDDS broadcasts. Dedicated TIBS and TDDS exercise channels were used by TMDSE during the test to preclude the broadcast of exercise tactical event messages into the actual scenario theater's operational network. Ongoing analysis of the collected data is currently being conducted.

For the HWILT-96, a northeast Asia scenario, including a dynamic environment of threats (theater ballistic missiles, aircraft, and cruise missiles), interceptors, weather, terrain, and threat/interceptor fragment debris was injected into the HWIL tactical weapon systems. The HWILT-96 test event employed real tactical TMD assets and operators, communicating via real-world tactical communication links responding in real time as if in an actual battlefield situation.

Future HWILTs will be executed and controlled from the BMDO JNTF, Falcon Air Force Base, Colorado Springs, Colo. Installation of the TMDSE Build 1 capability has been completed at the facility. Upon completion and demonstration, subsequent TMDSE builds will be installed at the JNTF for the operational execution of future TMD FoS tests.

The successful execution of the HWILT-96 enabled the establishment of policies and procedures for direction and conduct of future FoS tests, the development of lessons learned from the early use of TMDSE for FoS testing to support definition of future TMDSE enhancements, and early insight into FoS interoperability with respect to selected TMD Command and Control (C^2) Plan objectives. This experience, in conjunction with the full cooperation between BMDO, the operational test agencies, and the Services will make TMDSE the tool of choice whenever TMD system test and evaluation issues are addressed.

Leveraged Activities

The PEO-AMD provided critical support to Joint Project Optic Cobra (JPOC) '96 and Joint Exercise Roving Sands '96, conducted in June 1996. JPOC is an annual U.S. Central Command TMD exercise supported with BMDO funding. Conducted in the Fort Bliss, Texas, and White Sands Missile Range, N.M., areas as a part of the U.S. Forces Command-managed Joint Exercise Roving Sands, JPOC is the world's largest Joint Tactical Air Operations exercise. During the exercise, PEO AMD successfully implemented and executed the Cooperative Air and Missile Defense Network (CAMDEN), a distributed interactive simulation infrastructure capability that provides an integrated tactical missile and aircraft training environment for the U.S. and allied soldiers, sailors, airmen, and Marines participating in the Roving Sands exercise. Some CAMDEN components were derived from ongoing PEO AMD simulation and test and evaluation programs funded by BMDO, the Defense Modeling and Simulation Office, and from other Service and Joint programs. Particularly noteworthy, however, are the TMDSE-developed elements that include the PATRIOT Digital Flight Mission Simulator, the JTAGS simulator, the THAAD Test Controller, and the AEGIS weapon system at NSWC.

Summary

With declining resources, missile flight test costs are a major expense to program offices. Many constraints influence live flight tests such as range restrictions, treaty limitations, environmental concerns, and range safety issues. Program offices are no longer able to conduct the number of flight tests that they once did. A single flight test can cost from $25 to $50 million when target, interceptor, range, and personnel costs are figured in. In addition, the number of simultaneous engagements per test is limited to probably no more than two. However, weapon system interoperability assessment is required in a "target enriched" environment. For these reasons, HWIL testing is becoming increasingly important due to the significant cost savings that can be achieved by its use, and the TMDSE is being viewed as BMDO's key FoS test tool resource.

TMDSE is more economical than live flight tests and allows TMD systems to explore interoperability issues into areas not possible during live flight tests, such as multiple, simultaneous engagements and stressing environments. Expanding beyond range limitations as well as logistical considerations, TMDSE provides an economic solution to live flight tests.

The TMDSE is an integral part of BMDO's overall test and evaluation strategy that supports the successful acquisition of the TMD FoS. The strengths of the TMDSE include its design flexibility that facilitates the incorporation of new tactical weapon system elements by easily interfacing these elements into the distributed, real-time TMDSE network. As the TMD FoS evolves, the TMDSE will mature to meet the challenge of assessing the interoperability of these deployed weapon systems.

The "build-a-little, test-a-little" methodology implemented for the TMDSE will reduce development risks, pace the program to the funding appropriations, and tailor the "builds" to the TMD weapon system development schedules. The experience of the PEO AMD TMDSE development team has provided a solid foundation to leverage into the Build 3 development effort. This experience, in conjunction with the full cooperation between BMDO and the Services, will make TMDSE the tool of choice whenever TMD system test and evaluation issues are addressed.

For additional information on the TMDSE Program, visit **http://peoamd.redstone.army.mil/tmdse/** – our TMDSE Home Page on the World Wide Web.